U.S. and Worldwide Nuclear Energy

Left: The NRC participates in the annual International Conference for the International Atomic Energy Agency (IAEA) in Vienna, Austria. (Photo courtesy of IAEA)

Middle: NRC Chairman Gregory Jaczko signs an agreement strengthening U.S.-China nuclear safety cooperation at the Strategic and Economic Dialogue in China with Treasury Secretary Timothy Geithner and Secretary of State Hillary Rodham Clinton (left to right). (Pool Photo by Saul Loeb/AFP, via Getty Images)

Right: Building and flag of the International Atomic Energy Agency in Vienna, Austria. (Photo courtesy of IAEA)

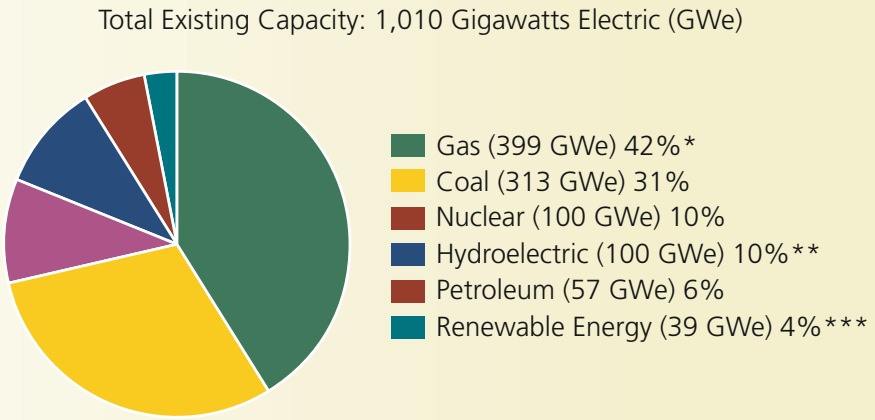
U.S. ELECTRICITY CAPACITY AND GENERATION

U.S. electric generating capacity totaled approximately 1,010 gigawatts in 2008 (see Figure 8), down slightly from 2007 (1,088 gigawatts). In 2008, the existing nuclear generating capacity totaled 100 gigawatts, which translates to 10 percent of total electric capacity. Since the 1970s, the Nation's utilities have used power uprates as a way to generate more electricity from existing nuclear plants. By January 2010, the NRC had approved 124 power uprates, resulting in a gain of approximately 5,726 megawatts electric (MWe) at existing plants. Collectively, these uprates have added the equivalent of five new reactors worth of electrical generation at existing plants. The NRC is reviewing or anticipating uprate applications totaling another 3,564 MWe (see Figure 9). In addition, license renewals will also add to projected electric capacity as shown in Figure 10.

As of April 2010, the 104 nuclear reactors licensed to operate accounted for approximately 20.2 percent of U.S. net electric generation at 799 billion kilowatthours (kWh) (see Figure 11).

As of April 2009, four States (New Jersey, South Carolina, Connecticut, and

Figure 8. U.S. Electric Existing Capacity by Energy Source, 2008



* Gas includes natural gas, blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuel.

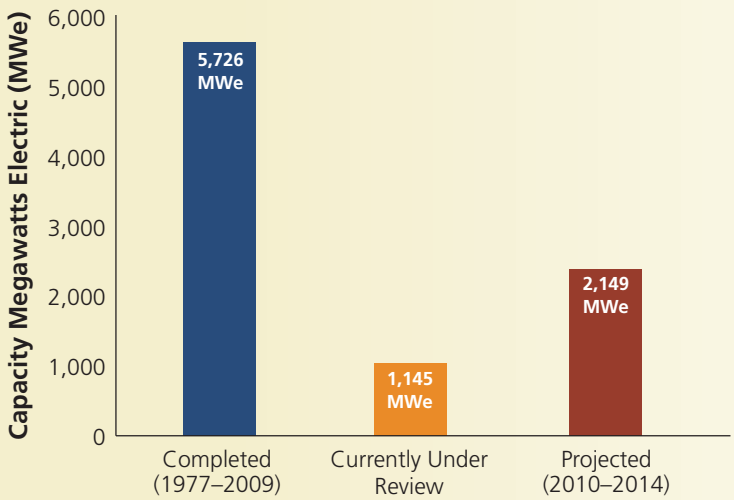
** Hydroelectric includes conventional hydroelectric and hydroelectric pumped storage.

*** Renewable energy includes geothermal, wood and nonwood waste, wind, solar energy, and miscellaneous technologies.

Note: Totals may not equal sum of components because of independent rounding. The amounts in parentheses are measured in gigawatts (a gigawatt is equal to 1,000 million watts), and the data used is summer existing capacity.

Source: U.S. Department of Energy/Energy Information Administration (DOE/EIA), "Electric Power Annual," Table 1.2, "Existing Capacity by Energy Source, 2008," January 21, 2010, www.eia.doe.gov

Figure 9. Power Uprates: Past, Current, and Future



Note: Power uprates have added the equivalent of five new reactors to the U.S. power grid.
Source: December 2009 survey of NRC Licenses.

Figure 10. Projected Electric Capacity Dependent on License Renewals

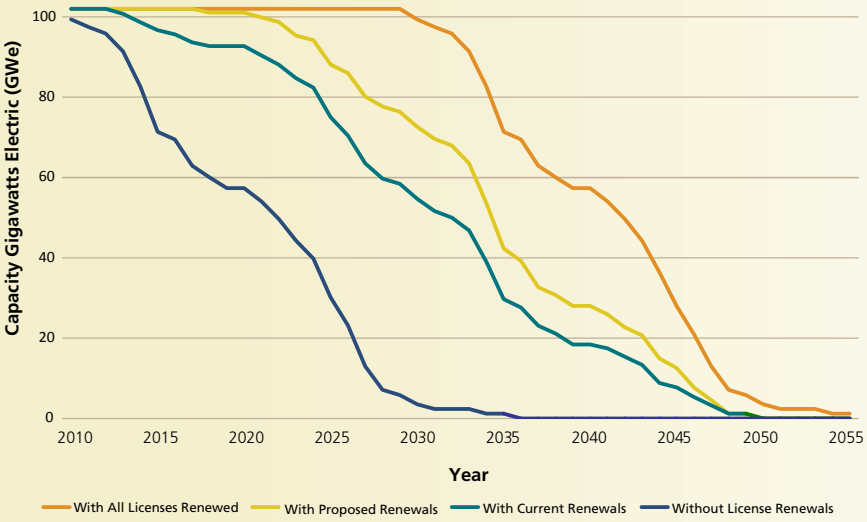
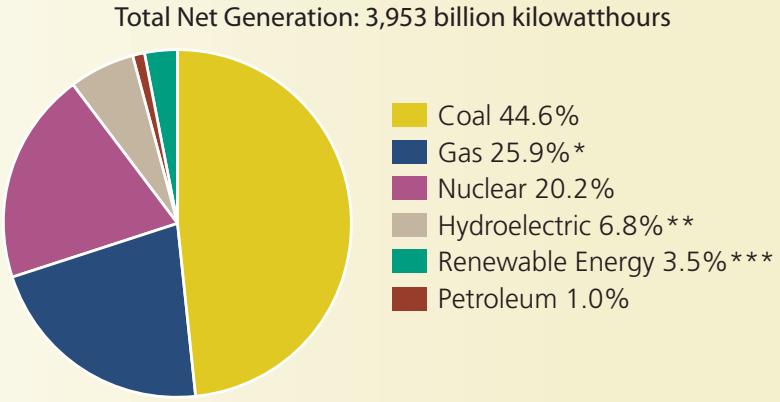


Figure 11. U.S. Electric Net Generation by Energy Source, 2009



* Gas includes natural gas, blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuel.

** Hydroelectric includes conventional hydroelectric and hydroelectric pumped storage.

*** Renewable energy includes geothermal, wood and nonwood waste, wind, and solar energy.

Note: Percentages are rounded to the nearest whole number. Totals may not equal sum of components because of independent rounding.

Source: DOE/EIA, "Monthly Energy Review," data from April 2009, www.eia.doe.gov/mer/

Vermont) relied on nuclear power for more than 50 percent of their electricity. The percentages cited reflect the percentages of the total net generation in these States that were from nuclear sources. An additional 12 States relied on nuclear power for 25 to 50 percent of their electricity (see Figure 12).

Since 1999, net nuclear electric generation has increased by 9.7 percent, and coal-fired electric generation has decreased by 6.2 percent (see Figure 13 and Table 1). All other electricity-generating sources have increased by 36.6 percent.

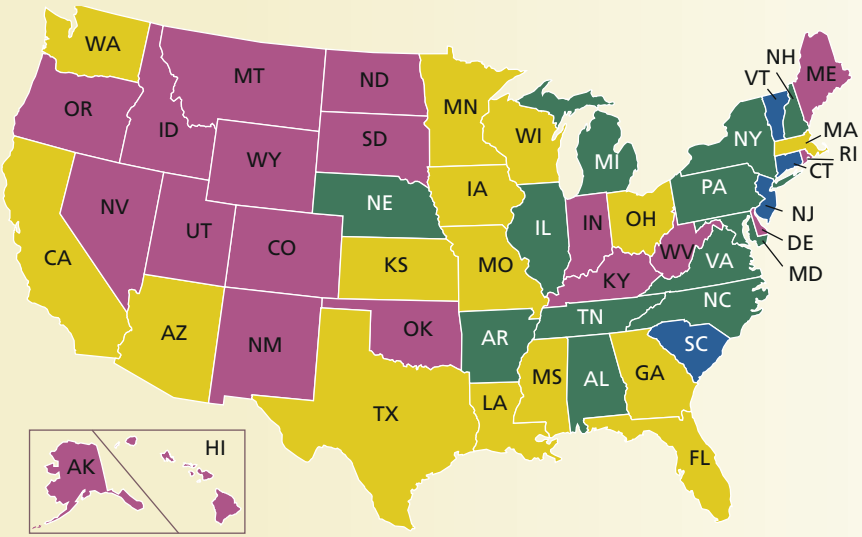
AVERAGE PRODUCTION EXPENSES

The production expense data presented in Table 2 and Figure 14 include all nuclear and fossil utility-owned steam electric plants. In 2008, production expenses averaged $21.16 each megawatthour for nuclear power plants and $35.67 each megawatthour for fossil fuel plants.

U.S. ELECTRICITY GENERATED BY COMMERCIAL NUCLEAR POWER

In 2009, net nuclear-based electric generation in the United States produced a total of 799 billion kilowatthours (see Table 3). In 2009, the average U.S. net capacity factor was 90.5 percent. Average U.S. net capacity factor—the ratio of electricity generated to the amount of energy that could have been generated—has increased by approximately 16 percent since 1998. In 2009, 98 percent of U.S. commercial nuclear reactors operated above an average net capacity factor of 70 percent (see Table 4).

Figure 12. Net Electricity Generated in Each State by Nuclear Power



Percent Net Generation from Nuclear Sources

None (19)

State	Net Capacity	Net Generation
Alaska	0	0
Colorado	0	0
Delaware	0	0
Hawaii	0	0
Idaho	0	0
Indiana	0	0
Kentucky	0	0
Maine	0	0
Montana	0	0
Nevada	0	0
North Dakota	0	0
New Mexico	0	0
Oklahoma	0	0
Oregon	0	0
Rhode Island	0	0
South Dakota	0	0
Utah	0	0
West Virginia	0	0
Wyoming	0	0

1% to 24% (16)

State	Net Capacity	Net Generation
Arizona	15	24
California	7	16
Florida	7	15
Georgia	11	23
Iowa	4	10
Kansas	10	18
Louisiana	8	17
Massachusetts	5	14
Minnesota	12	24
Mississippi	8	19
Missouri	6	10
Ohio	6	11
Texas	5	10
Washington	4	8
Wisconsin	9	19

25% to 50% (12)

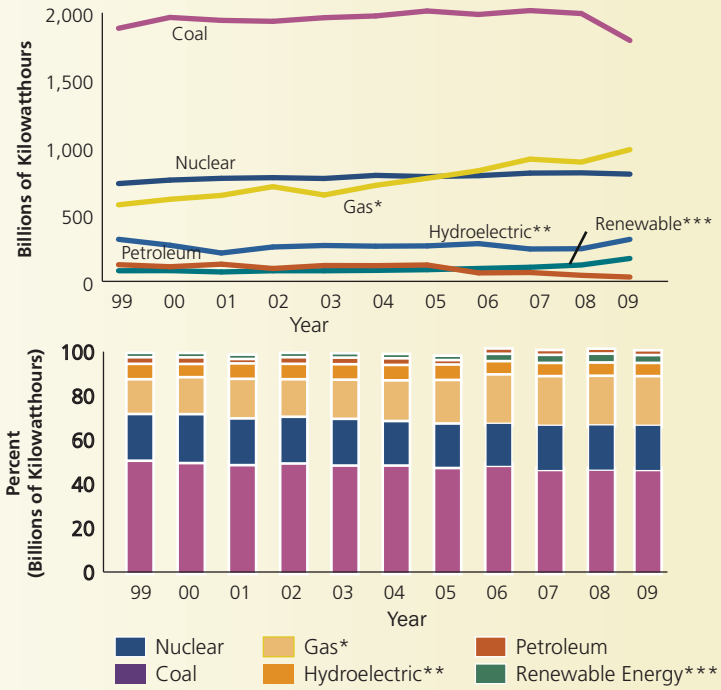
State	Net Capacity	Net Generation
Alabama	16	27
Arkansas	12	26
Illinois	26	48
Maryland	14	31
Michigan	13	27
Nebraska	18	29
New Hampshire	30	41
New York	14	31
North Carolina	18	32
Pennsylvania	21	35
Tennessee	16	30
Virginia	14	38

More than 50% (4)

State	Net Capacity	Net Generation
Connecticut	26	51
New Jersey	22	51
South Carolina	27	51
Vermont	55	72

Note: Percentages are rounded to the nearest whole number. Units measured are in megawatts.
Source: DOE/EIA, "State Electricity Profiles," data from April 2010, www.eia.doe.gov

Figure 13. U.S. Net Electric Generation by Energy Source, 1999–2009



* Gas includes natural gas, blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuel.

** Hydroelectric includes conventional hydroelectric and hydroelectric pumped storage.

*** Renewable energy includes geothermal, wood and nonwood waste, wind, and solar energy.

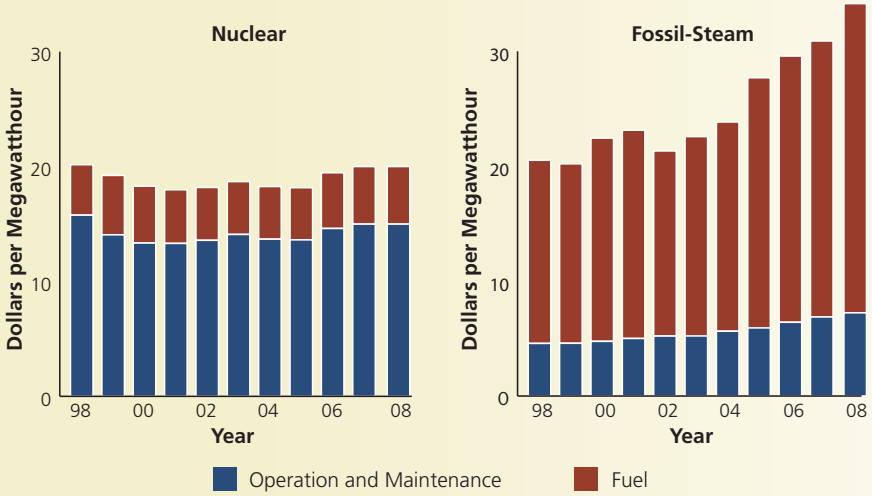
Source: DOE/EIA, "Monthly Energy Review," Table 7.2a, April 2010, www.eia.doe.gov

Table 1. U.S. Net Electric Generation by Energy Source, 1999–2009 (Billion Kilowatthours)

Year	Coal	Petroleum	Gas*	Hydroelectric**	Nuclear	Renewable Energy***
1999	1,881	118	570	313	728	79
2000	1,966	111	614	270	754	81
2001	1,904	125	648	208	769	71
2002	1,933	95	702	256	780	79
2003	1,973	119	665	267	764	79
2004	1,977	120	726	260	788	83
2005	2,013	122	774	264	782	87
2006	1,990	64	829	283	787	96
2007	2,016	66	910	241	806	105
2008	1,986	46	895	248	806	126
2009†	1,764	39	1,027	268	799	141

Note: See footnotes for Figure 12. † Based on preliminary data.
Source: DOE/EIA, "Monthly Energy Review," Table 7.2a, April 2010, www.eia.doe.gov

Figure 14. U.S. Average Nuclear Reactor and Fossil-Steam Plant Production Expenses, 1998–2008



Source: Federal Energy Regulatory Commission, FERC Form 1, "Annual Report of Major Electric Utilities, Licensees and Others"; DOE/EIA, "Electric Power Annual," January 21, 2010, www.eia.doe.gov

Table 2. U.S. Average Nuclear Reactor and Fossil-Steam Plant Production Expenses, 1998–2008 (Dollars per Megawatthour)

Year	Operation and Maintenance	Fuel	Total Production Expenses
Nuclear			
1998	15.77	5.39	21.16
1999	14.06	5.17	19.23
2000	13.34	4.95	18.28
2001	13.31	4.67	17.98
2002	13.58	4.60	18.18
2003	14.09	4.60	18.69
2004	13.68	4.58	18.26
2005	13.62	4.54	18.16
2006	14.61	4.85	19.46
2007	14.99	5.01	20.00
2008	15.88	5.29	21.16

Year	Operation and Maintenance	Fuel	Total Production Expenses
Fossil-Steam*			
1998	4.58	15.94	20.52
1999	4.59	15.62	20.22
2000	4.76	17.69	22.44
2001	5.01	18.13	23.14
2002	5.22	16.11	21.32
2003	5.23	17.35	22.59
2004	5.64	18.21	23.85
2005	5.93	21.77	27.69
2006	6.42	23.17	29.59
2007	6.88	24.02	30.89
2008	7.24	28.43	35.67

* Includes coal and fossil fuel. Plant production expenses are no longer available exclusively for coal-fired fuel.

Note: Expenses are average expenses weighted by net generation. Totals may not equal sum of components because of independent rounding.

Source: Federal Energy Regulatory Commission, FERC Form 1, "Annual Report of Major Electric Utilities, Licensees and Others," DOE/EIA, "Electric Power Annual," January 21, 2010, www.eia.doe.gov

Table 3. U.S. Nuclear Power Reactor Average Net Capacity Factor and Net Generation, 1999–2009

Year	Number of Operating Reactors	Average Net Capacity Factor (Percent)	Net Generation of Electricity	
			Billions of Kilowatthours	Percent of Total U.S. Capacity
1999	104	85	728	19.7
2000	104	88	754	19.8
2001	104	89	769	20.6
2002	104	90	780	20.2
2003	104	88	764	19.7
2004	104	90	788	19.9
2005	104	89	782	19.3
2006	104	90	787	19.4
2007	104	92	806	19.4
2008	104	91	806	19.6
2009*	104	90	799	20.2

* Based on preliminary data.

Note: Average net capacity factor is based on net maximum dependable capacity. See Glossary for definition.

Source: Based on DOE/EIA, "Monthly Energy Review," Table 8.1, April 2010, www.eia.doe.gov, and licensee data as compiled by the U.S. Nuclear Regulatory Commission

Table 4. U.S. Commercial Nuclear Power Reactor Average Capacity Factor by Reactor Type, 2007–2009

	Nuclear Power Plants Licensed To Operate			Percent of Net Nuclear Generated		
Capacity Factor	2007	2008	2009*	2007	2008	2009*
Above 70 Percent	101	101	99	98	98	97
50 to 70 Percent	2	3	4	1	2	3
Below 50 Percent	1	0	1	<1	0	<1

	Nuclear Power Plants Licensed To Operate			Average Capacity Factor (Percent)		
Reactor Type	2007	2008	2009*	2007	2008	2009*
Boiling-Water Reactor	35	35	35	90	93	90
Pressurized-Water Reactor	69	69	69	93	91	90
Total	104	104	104	N/A	N/A	N/A

*Based on preliminary data.

Note: Average capacity factor is based on net maximum dependable capacity. See Glossary for definition. Refer to Appendix A for the 2007–2009 average capacity factors for each reactor. Percentages are rounded to the nearest whole number.

Source: Licensee data as compiled by the U.S. Nuclear Regulatory Commission

WORLDWIDE ELECTRICITY GENERATED BY COMMERCIAL NUCLEAR POWER

As of 2010, there were 438 operating reactors in 30 countries and Taiwan with a total installed capacity of 373,006 gigawatts electric (GWe) (see Figure 15). In addition, five nuclear power plants were in long-term shutdown, and 54 nuclear power plants were under construction.

See Appendix J for a list of the number of nuclear power reactors by nation and Appendix K for nuclear power units by reactor type, worldwide.

WORLDWIDE NUCLEAR PRODUCTION

The United States produced approximately 27 percent of the world's gross nuclear-generated electricity in 2009 (see Figure 16). France was the next highest producer at 17 percent. Based on preliminary data in 2009, France had the highest nuclear portion (75 percent) of total domestic energy generated. In the United States, nuclear energy accounted for 20 percent of the domestic energy generated (see Figure 17).

Countries with the highest average gross capacity factor for nuclear reactors in 2009 include South Korea at 90 percent, the United States at 89 percent, Russia at 73 percent, and France at 71 percent (see Table 5).

Table 5. Commercial Nuclear Power Reactor Average Gross Capacity Factor and Gross Generation by Selected Country, 2009

Country	Number of Operating Reactors	Average Gross Capacity Factor (in percent)	Total Gross Nuclear Generation (in billions of KWh)	Number of Operating Reactors in Top 50 by Capacity Factor	Number of Operating Reactors in Top 50 by Generation
Canada	21	65	91	0	0
France	58	71	410	0	9
Germany	17	69	135	0	10
Japan	56	65	272	8	2
Korea, South	20	90	147	5	0
Russia	31	73	163	0	0
Sweden	10	64	52	0	0
Ukraine	15	66	82	0	0
United States	104	89	833	27	26

Note: The U.S. gross capacity factor and generation include estimates based on net MWh for 4 of the 104 U.S. units. The country's short-form name is used.

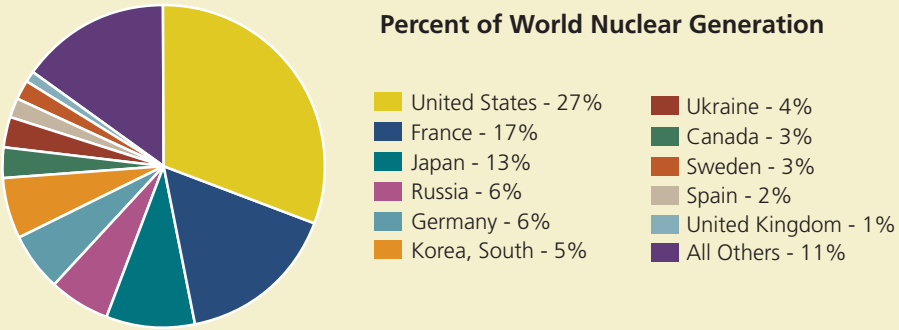
Source: Excerpted from Nucleonics Week©, 2010, by McGraw-Hill, Inc. Reproduced by permission.

Figure 15. Operating Nuclear Power Plants Worldwide

Note: There are no commercial reactors in Alaska or Hawaii. Refer to Appendix J for a world list of the number of nuclear power reactors.

Source: Nucleonics Week© and International Atomic Energy Agency

Figure 16. Gross Nuclear Electric Power as a Percent of World Nuclear Generation, 2009



Note: Because of independent rounding, the figures may not add up to the total percentage. The country's short-form name is used.

Source: International Atomic Energy Association, Power Reactor Information System, as of May 6, 2010

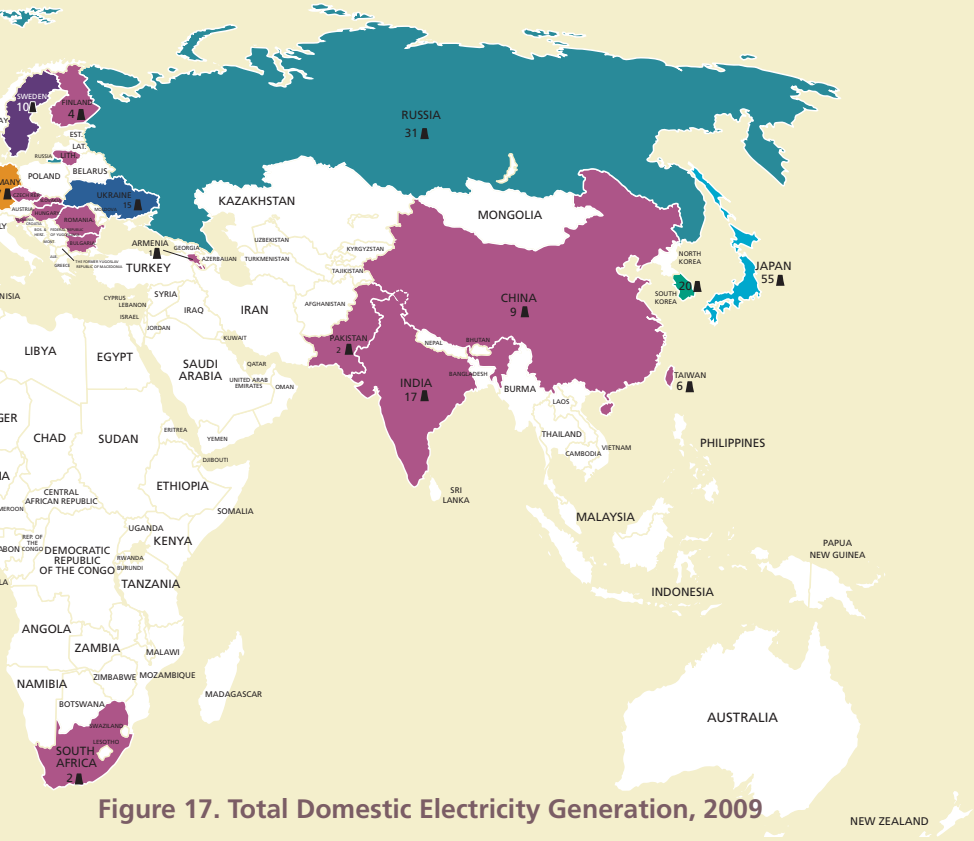
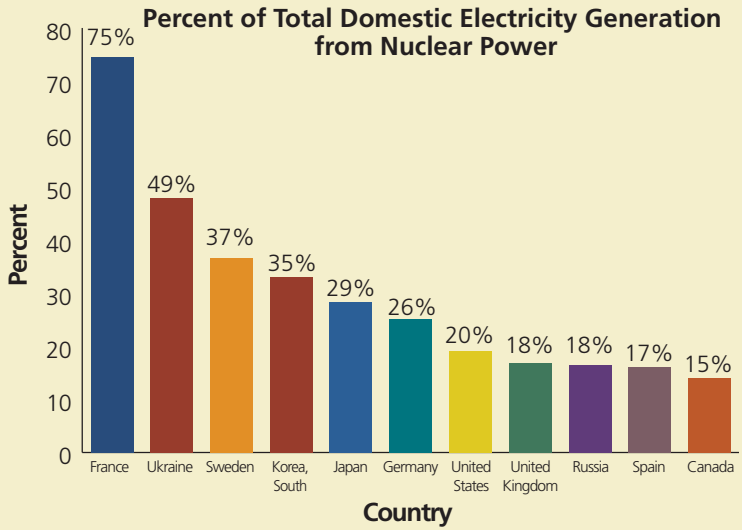


Figure 17. Total Domestic Electricity Generation, 2009



Note: The country's short-form name is used.

Source: International Atomic Energy Association, Power Reactor Information System, as of May 6, 2010

Table 6. Commercial Nuclear Power Reactor Average Gross Capacity Factor by Selected Country, 2000–2009

Annual Gross Average Capacity Factor (Percent)

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009*
Canada	50	53	53	54	64	66	71	67	67	66
France	72	73	75	75	77	78	77	76	76	74
Germany	87	87	83	84	87	86	89	73	77	73
Japan	79	79	77	59	70	69	70	64	59	62
Korea, South	90	93	93	94	92	95	93	88	93	90
Russia	67	67	67	70	68	66	70	71	73	72
Sweden	66	84	75	77	89	87	82	80	78	74
Ukraine	69	74	75	78	76	72	74	75	73	71
United States	87	88	89	87	90	87	88	91	90	90

* 2009 based on preliminary data.

Note: Percentages are rounded to the nearest whole number. The country's short-form name is used.

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Reactors in the United States had the greatest gross nuclear generation at 842 billion kilowatthours. France was the next highest producer at 410 billion kilowatthours (see Table 5).

See Appendix L for a list of the top 50 reactors by gross capacity factor worldwide, and refer to Appendix M for a list of the top 50 reactors by gross generation worldwide.

Over the past 10 years, the average annual gross capacity factor has increased 3.5 percent in the United States and 2.7 percent in France. In the same period, the average annual gross capacity factor has decreased 21.5 percent in Japan and 16 percent in Germany (see Table 6).

INTERNATIONAL ACTIVITIES

The NRC must perform certain legislatively mandated international duties. These include licensing the import and export of nuclear materials and equipment and participating in activities supporting U.S. Government compliance with international treaties and agreement obligations. The NRC has bilateral programs of assistance or cooperation with 40 countries and Taiwan (see Table 7). The NRC has also supported U.S. Government nuclear safety initiatives with countries in Europe, Africa, Asia, and Latin America. In addition, the NRC actively cooperates with multinational

organizations, such as the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA), a part of the Organisation for Economic Co-operation and Development. The NRC also has a robust international cooperative research program.

Since its inception, the agency has hosted over 300 foreign nationals in on-the-job training assignments at NRC Headquarters and the regional offices. The NRC's Foreign Assignee Program helps instill regulatory awareness, capabilities, and commitments in foreign assignees. It also helps to enhance the regulatory expertise of both foreign assignees and NRC staff. Additionally, the program improves international channels of communication through interaction with the international nuclear community and development of relationships with key personnel in foreign regulatory agencies.

Table 7. Bilateral Information Exchange and Cooperation Agreements with the U.S. Nuclear Regulatory Commission

Agreement Country	Renewal Date
Argentina	2012
Armenia	2012
Australia	2013
Belgium	2014
Brazil	2014
Bulgaria	2011
Canada	2012
China	2013
Croatia	2013
Czech Republic	2014
Egypt	1991
EURATOM	2014
Finland	2011
France	2013
Germany	2012
Greece	2013
Hungary	2012
Indonesia	2013
Israel	2010
Italy	2010
Japan	2012

Agreement Country	Renewal Date
Kazakhstan	2014
Korea, South	2010
Lithuania	2010
Mexico	2012
Netherlands	2013
Peru	Open-Ended
Philippines	Open-Ended
Poland*	2010
Romania	2010
Russia	2001
Slovakia	2010
Slovenia	2010
South Africa	2010
Spain	2010
Sweden	2011
Switzerland	2012
Ukraine	2011
United Arab Emirates*	2010
United Kingdom	2013
Vietnam	2013

* In negotiation

Note: The NRC also provides support to the American Institute in Taiwan. Egypt's agreement has been deferred until its regulatory body requests reinstatement. Russia's agreement is still in negotiation. The country's short-form name is used.

EURATOM—The European Atomic Energy Community

Through its export/import authority, the NRC upholds the U.S. Government goals of limiting the proliferation of materials that could be used in weapons and supports the safe and secure use of civilian nuclear and radioactive materials worldwide. In addition to its direct export/import licensing role, the NRC consults with other U.S. Government agencies on international nuclear commerce activities falling under their authority. The NRC continues to work to strengthen the export/import regulations of nuclear equipment and materials, and to improve communication between domestic and international stakeholders.

The NRC assists in implementing the U.S. Government's international nuclear policies through developing legal instruments that address nuclear nonproliferation, safety, international safeguards, physical protection, emergency notification and assistance, spent fuel and waste management, and liability. The NRC also participates in the negotiation and implementation of U.S. bilateral agreements for peaceful nuclear cooperation under Section 123 of the U.S. Atomic Energy Act of 1954, as amended. The NRC also ensures licensee compliance with the U.S. Voluntary Safeguards Offer agreement with IAEA. This agreement was amended on December 31, 2008, when the United States signed the "Protocol Additional to the U.S.-International Atomic Energy Agency Agreement for the Application of Safeguards in the United States." The Additional Protocol entered into force on January 6, 2009, and the United States submitted its first annual declaration to IAEA in July 2009.

The NRC also participates in a wide range of mutually beneficial international exchange programs that enhance the safety and security of peaceful nuclear activities worldwide. These low-cost, high-impact programs provide joint cooperative activities and assistance to other countries to develop and improve regulatory organizations. The NRC engages in the following activities:

- Cooperates with countries with mature nuclear programs to ensure the timely exchange of applicable nuclear safety and security information relating to operating reactors and consults with these countries on new reactor-related activities.
- Ensures prompt notification to foreign partners of U.S. safety issues, notifies NRC program offices about foreign safety issues, and shares security information with selected countries.
- Initiates bilateral discussions in such regulatory areas as licensing, inspection, and enforcement with countries that have recently built facilities or have vendors of equipment that may be imported to the United States during the anticipated construction of new nuclear power plants.
- Participates in the Multinational Design Evaluation Program, which leverages the resources of interested regulatory authorities to review new designs of nuclear power reactors.
- Assists other countries to develop and improve regulatory programs through training, workshops, peer

review of regulatory documents, working group meetings, and exchanges of technical information and specialists.

- Assists countries to ensure regulatory control over radioactive sources through development of standards and provision of training and workshops through a pilot program begun in 2008.
- Participates in the multinational programs of IAEA and NEA concerned with safety research and regulatory matters, radiation protection, risk assessment, emergency preparedness, waste management, transportation, safeguards, physical protection, security, standards development, training, technical assistance, and communications.
- Participates in the International Nuclear Regulators Association meetings to influence and enhance nuclear safety from the regulatory perspective. Its members are the most senior officials of well-established independent national nuclear regulatory organizations. Current members are Canada, France, Germany, Japan, South Korea, Spain, Sweden, the United Kingdom, and the United States.
- Meets through the NRC's Advisory Committee on Reactor Safeguards with other international advisory committees every 4 years to exchange information.
- Participates in joint cooperative research programs through approximately 100 multilateral agreements with 23 countries to leverage access to foreign test facilities not otherwise available to the United States. Access to foreign test facilities expands the NRC's knowledge base and contributes to the efficient and effective use of the NRC's resources in conducting research on high-priority safety issues.

NRC staff participates in an international exchange seminar to learn about the construction experience of the Finnish regulatory agency.